Print on Demand for Nautical Charting Products

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Introduction

Print on Demand is the use of large format plotters and computer technology to print nautical charts at the moment they are wanted. The technology, however, is capable of far more than serving as a replacement for traditional printing methods. While the technology is not difficult, using it to achieve the greatest benefits for mariners adds substantially to the complexity.

NOAA began experimenting with Print on Demand in 1996, and began selling Print on Demand nautical charts as an official product in 2000. NOAA's Print on Demand charts are made under a public/private partnership with OceanGrafix, LLC, a private company in St. Paul, Minnesota. This paper will discuss the uses of Print on Demand for nautical charting products, the technology, NOAA's experience, and mariner reactions to the results.

Uses of Print on Demand in Nautical Charting

At the simplest level, Print on Demand technology can be used as a replacement for traditional lithographic printing. In this mode, it can:

- reduce or eliminate the inventory and warehousing costs of nautical charting;
- insure that copies are always available by printing charts whenever they are ordered, or in small quantities for a chart agent's inventory that is replenished as needed;
- eliminate the wasteful destruction of obsolete charts in the warehouse when a new edition is issued;
- permit the use of a variety of different papers for charts;
- avoid a reprint when inventory is depleted but when a new edition is imminent;
- permit point-of-purchase printing.

This use of Print on Demand is especially well suited for charts that sell small quantities. With sufficient attention to a means of quality control at remote printing sites, it would be possible for governments to stop the actual printing of charts by letting retailers print the charts they sell. Training and licensing might be appropriate for this use of Print on Demand.

At a more advanced level, the simple process of plotting pre-assembled digital charts can be augmented with additional computer infrastructure. The addition of computer-assisted cartography, near real-time chart file(s) maintenance, the dynamic assembly of files, and electronic ordering can produce additional benefits for mariners such as:

- making nautical charts that are up-to-date at the moment they are printed thus providing charts that have been professionally corrected by hydrographic offices;
- allowing charts to be customized for different market segments, such as commercial mariners, recreational boaters, and coastal zone managers;
- providing customized charts for individual customers, such as by adding course lines, or corporate information printed outside the chart neat line;
- supporting different versions of the same chart, such as with and without LORAN;
- providing a subscription service that delivers a professionally updated chart whenever there is a Notice to Mariners correction;
- the benefits of reduced or eliminated inventory and warehousing costs are still achieved if these advanced benefits are targeted.

At NOAA, it was decided that the best application of Print on Demand would be the provision of up-to-date charts. Therefore, a system with the advanced capabilities was implemented.

Print on Demand Technology

Printing Technology – The technology for Print on Demand is readily available. Large format, full color plotters come in several varieties (ink jet, electrostatic, solid ink, piezoelectric), and at several different prices from a few thousand to several hundred thousand USD per plotter. Ink jet plotters are emerging as the most commonly used large format plotters due to their low initial cost, ease of use, variety of paper and inks, and acceptable image quality. They offer a range of dots-per-inch resolutions with the mid-range being acceptable for nautical charts. They also offer a good range of color control. Inexpensive personal computers and commercially available software are all that is needed to operate and manage these devices. Brand name plotters are proving to be quite reliable as a low to medium volume production tool.

Ink jet plotters, however, have some drawbacks. It usually take several minutes to plot a chart-sized image, and the image quality, while more than adequate for its purpose, is not as good as lithographically printed charts. A perfect color match to printed charts is not easy if that is one's goal. With many combinations of ink and paper, the image is not very durable and may smear when wet or erase easily when course lines are added or removed. Hydrographic offices evaluating Print on Demand should also consider how they will cut a chart to its finished size if that is necessary.

Suitable plotters are available worldwide and many hydrographic offices already have experience with equipment that could be used. A market survey of plotters is not included here since this technology is improving at a rapid pace, and different equipment is available in different countries.

NOAA and OceanGrafix selected a well known ink jet plotter based on price, reliability, plot speed, paper width, available papers, and brand reputation. Additional plotters are added as volume requirements increase. The changed image quality was handled by changing the chart colors to a brighter set, thus intentionally changing the user's expectations – a tactic that worked effectively.

Materials – Papers for ink jet plotters are available with a wide variety of characteristics and prices. Coated papers made for ink jet plotters clearly give the best image quality results. An appropriate combination of paper tear strength, water and ultraviolet resistance, available width, and cost is needed. In field trials, mariners were sensitive to their ability to write and erase on the material, the ability to fold it repeatedly, and the general heft or "feel" of the paper. Paper that was too thin and felt flimsy received negative comments. It is an added benefit of Print on Demand that, because no inventory of copies is kept, several papers can be offered to mariners with the appropriate paper used at plot time.

Inks for ink jet plotters are also available with a wide variety of characteristics and prices. Water-fastness, ultraviolet resistance, and price are factors to consider in selecting inks. Some inks are solvent-based rather than water-based, and emit noxious fumes. Most plotters allow a wide range of colors to be simulated, but different plotter/paper/ink combinations will give different appearances. Hydrographic offices establishing a Print on Demand capability will need to select a color set by trial and error that is appropriate for the plotter/paper/ink combination they are using.

The materials used for Print on Demand are significantly more expensive than those used for lithographic printing. If Print on Demand is being considered to avoid inventory and warehouse costs, or to avoid printing costs for low volume charts, one can determine the cost for Print on Demand using equipment, paper and inks available in the local market, and then calculating the breakeven number of copies at which Print on Demand is less expensive than alternative methods of printing and storing.

OceanGrafix chose inks and an inexpensive paper made for the plotter that was selected, and then laminated the result with a proprietary lamination to achieve water-resistance and tear strength. While generally well accepted, there have been a few comments that the result does not fold as flat as paper, and that the chart tends to slip off the chart table in heavy weather. OceanGrafix then added a water-resistant paper to its offering, and mariners may choose whichever best suits their needs.

Supporting Technology – No special computer technology is needed to use Print on Demand as an alternative printing method. Chart files, which may be large, can be prepared in advance and stored on a hard drive or network. Orders for copies simply go to a plotting facility rather than a warehouse. Existing administrative systems for print management, shipping, billing and collecting revenues do not need to change. Software to plot copies of a chart is simple to operate. The only real requirement is for digital files. A file resolution of 300 dots per inch is adequate although bar codes may not be readable. File resolutions greater than 600 dots per inch do not appear to provide any further improvement in readability for a standard nautical chart.

Advanced Computer Requirements – Substantial computerization is necessary to achieve the advanced benefits of making up-to-date charts and customization. Computerized cartography is needed to keep the digital charts updated daily or weekly. At NOAA, the charts are maintained as raster images that are updated weekly for all Notices to Mariners. These same updated raster files are used in the NOAA/Maptech raster nautical chart update service. Custom data is maintained as digital overlays, or as additional files to be plotted outside the chart neat line.

A suitable file management system is needed to keep track of the asynchronously changing files that make up a Print on Demand chart. NOAA has at least 3 different groups that may be changing the approximately 20 files making up a Print on Demand chart. File naming conventions that support versioning, file management software, and work flow management all help to see that the right files and right versions are combined automatically when a chart is ordered to be printed.

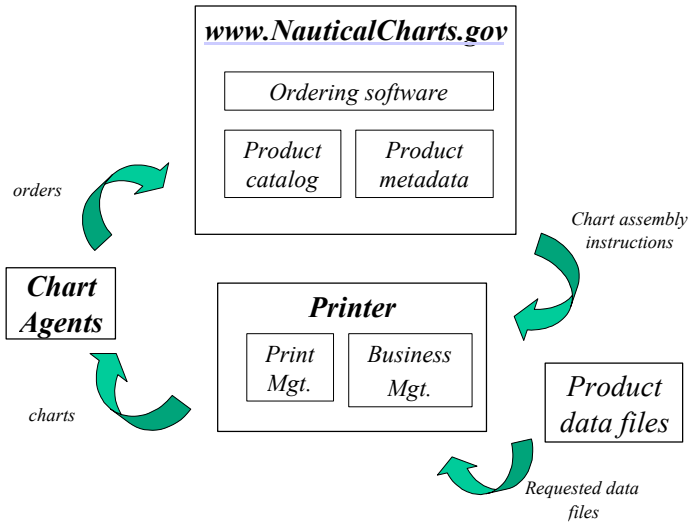

Figure 1 - NOAA Print on Demand Block Diagram

Finally, an electronic commerce system was added for two purposes. First, it is an e-commerce site for chart agents to place their orders. Second, it is part of the chart production software. In this role, it writes an electronic message containing assembly instruction for each chart ordered. Lastly, the message contains the administrative information about the order such as the customer and the number of copies. A block diagram of the Print on Demand/e-Commerce system being used by NOAA and OceanGrafix is shown in Figure 1.

NOAA's Experience with Print on Demand – NOAA and OceanGrafix began selling Print on Demand nautical charts in September, 2000 in a test mode. The purposes of this test were to determine:

- product acceptability;
- retail price acceptability;
- production costs and times; and
- to test a full production system in a mini-production mode.

The test started with 41 charts and 6 retail chart agents. The laminated product was offered in 2 versions, one for commercial mariners and one for recreational mariners. The commercial version had extra information printed outside the chart neat line such as bridge clearances, tide correctors, radio frequencies, phone numbers, and text from NOAA's Coast Pilot (Figure 2). The recreational version had extra information dealing with safety and boating. The electronic commerce system was used for chart ordering, but automatic chart assembly was not fully functional.

The test ran for 16 months and grew to 268 charts and 19 chart sales agents. Over 10,000 charts were sold. Mariners were interviewed by NOAA, OceanGrafix and the chart agents. Surveys were distributed and analyzed. A small number of failed products were returned for examination.

The results of this test were conclusive. Mariners overwhelmingly described the physical characteristics and utility for navigation of the Print on Demand chart as excellent or good. The most admired feature

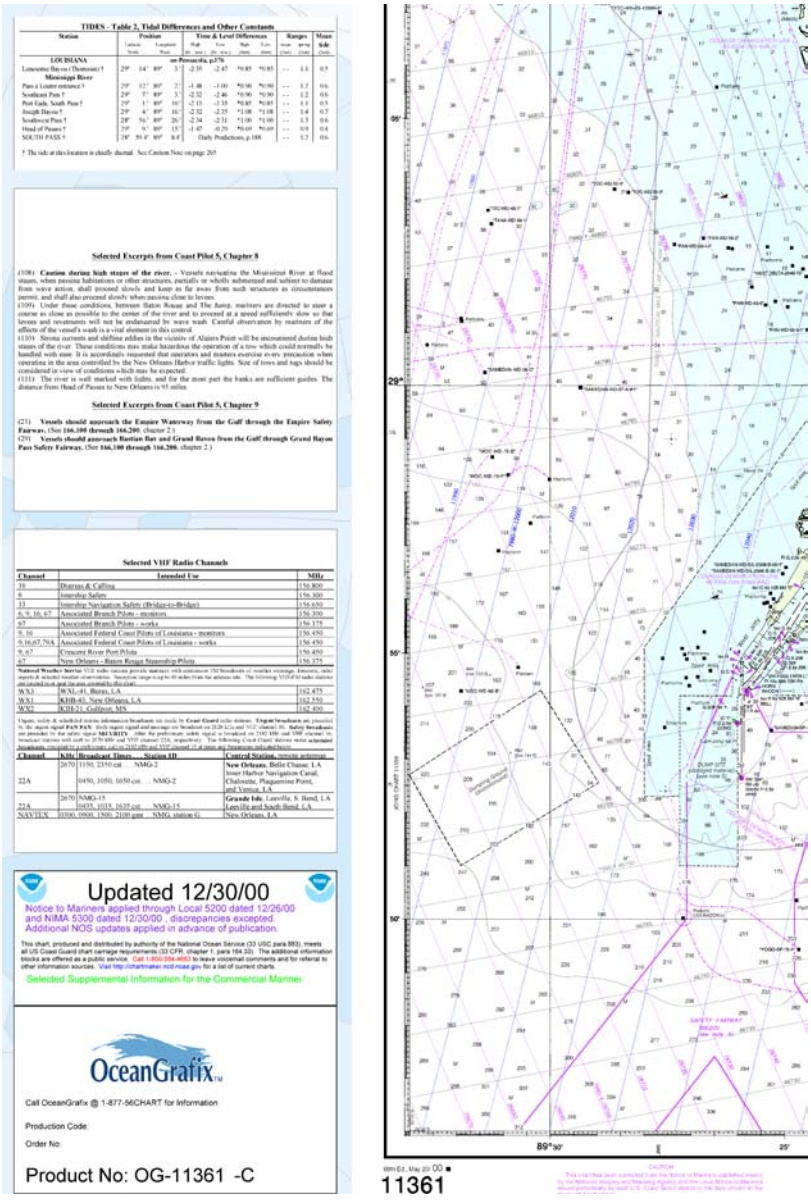

Figure 2 - Extra Information Added Outside the Chart Neat Line

was that they were up-to-date with all critical safety information. One hundred percent of responding commercial mariners thought the up-to-date feature was extremely important. Mariners liked the durable, water resistant nature of the chart and the chart's new colors, contrast, and readability. The extra information in the margin of the chart was also rated as important. Seventy-two percent said the tide tables were important; 89 percent said that bridge clearances were important; 41 percent said phone numbers and Internet addresses were important; 71 percent said excerpts from the Coast Pilot were important; and 95 percent said VHF radio frequencies were important.

The overall size of the chart was criticized – a situation made worse by the extra 6 inches added for the information in the margin. Comments were also received that the laminated chart folded less well than paper, and there were 2 or 3 laminate failures. A water resistant paper was introduced to counter these shortcomings, but it had it's own problems – namely that writing and erasing were less acceptable.

The price of the up-to-date Print on Demand chart was 20 USD during the test. For reference, NOAA's traditional lithographic chart sells for 17.50 USD. This higher price was overwhelmingly found to be acceptable. While there were some who thought the price too high, a comparable number thought the improved value of the Print on Demand would be worth at least 25 USD. Recreational boaters were probably underrepresented in this evaluation of price acceptability compared to their share of overall chart purchases.

Costs were found to be slightly higher than anticipated before the test began. Paper and ink costs were part of the reason since product acceptability was given a higher priority than retail cost. In addition, order handling costs had not been accurately estimated.

Production times were better than expected. The original goal was to put corrected charts in mariner's hands by the time they would receive the Notice to Mariners in the mail. Three activities take place to do this. First, NOAA must update all charts, every week, for all Notice to Mariner items. Then, the Print-on-Demand e-commerce site (www.NauticalCharts.gov) must automatically update its metadata, assembly instructions, and catalog so orders use the new data. Finally, OceanGrafix must import and preprocess changed chart files, and manufacture and ship charts. At present, NOAA is applying all NTM items within the 5-day advanced receipt window it has for the Notices, and has been doing so for 2 ½ years. The ordering website www.NauticalCharts.gov automatically updates itself for these changes every 30 minutes. OceanGrafix reacts to the changes, preprocesses some data, and manufactures charts. As a result, chart changes made by NOAA are effective within 30 minutes. Orders received in that 30-minute window are automatically held by the system and released for fulfillment only after the new data is on-line.

The final purpose of the test was to exercise a full, production system in a pilot mode. This was successfully accomplished during the 16 month test. The management of multiple printers has been achieved. Integration with back office systems for billing, accounting, and record keeping to support the full suite of charts and an expanded network of agents is complete. Processes to perform order handling, packing and shipping have been put in place as has marketing, agent support, and customer service.

Present Status – Four hundred seventy-seven of NOAA's 1,000 charts are available as up-to-date, Print on Demand charts (February, 2002). The rest will be released in batches during 2002. The charts are up-to-date with all Notice to Mariners and other critical information when they are printed. Orders received by 11:30 a.m. are shipped by the next business day. Two versions of the charts are available: commercial[1] and recreational, and either version may be ordered on laminated or water-resistant paper.

All Print on Demand charts are ordered using the e-commerce site which also takes agent orders for the traditional lithographic charts. Five hundred of NOAA's 1,300 agents have logged on to the site and 375 have placed orders using it. At present, 19 agents are carrying Print on Demand charts as part of the test program, a number soon to be increased.

Extension of the Concept – Implementing the advanced capabilities for Print on Demand gives the opportunity for a broad range of products. With automated file management and dynamic chart assembly, a natural extension is to create custom charts. At NOAA, the capability of automatically overlaying the chart with routes and operational areas for the Coast Guard has been successfully tested (Figures 3a, 3b, 3c). The capability of replacing the information plotted outside the chart neat line with a customer's information has also been demonstrated. This has been used, for example, to add a selling agent's business card to charts.

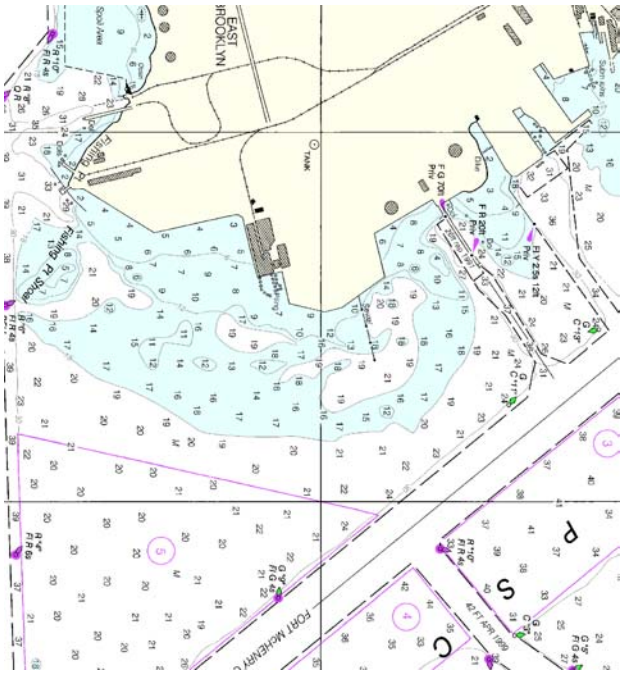

Figure 3a - Chart Segment Without Custom Overlay

The capability of dynamically assembling digital files at plot time has also been used to make charts with and without LORAN lines. This has been an awkward issue for NOAA which has advocates on

[1] Note: Not all NOAA charts will be produced in the commercial version. Only those covering locations and scales that support commercial navigation will be offered as such – about 45% of NOAA chart suite. All charts will be offered in the recreational version.

both sides of the LORAN issue. For Print on Demand charts, an agent can indicate LORAN as an option when placing an electronic order, and the appropriate files will automatically be called for in the assembly instructions used to print the chart.

A third use of the advanced Print on Demand technology being tested is the production of a reduced scale, "Pocket Chart" for day sailors. These boaters are characterized as having open boats, 18 to 22 feet in length, and who presently use no navigation products. A small, inexpensive, impulse purchase product has the potential of serving these boaters as a "locater" with boating safety information printed on the back.

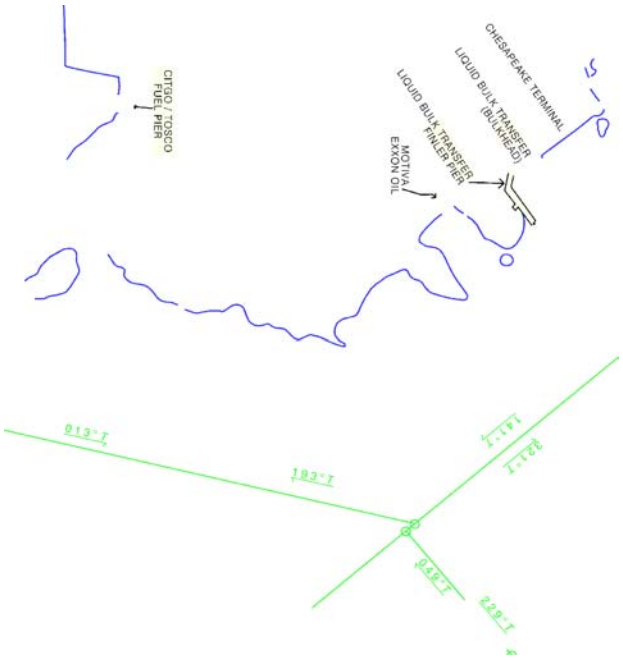

Figure 3b - Custom Chart Overlay

The process to make this Pocket Chart is the same as before – metadata in the e-commerce system tells what chart files and overlays to assemble, including those for the reverse side. As an added twist, the print system is told to reduce the files by two-thirds to fit a 13" x 19" piece of paper. This will also be our first attempt at 2-sided printing with the Print on Demand system. Using Print on Demand gives a low cost way to test new products like this, and to change them rapidly as feedback is received from boaters and retailers.

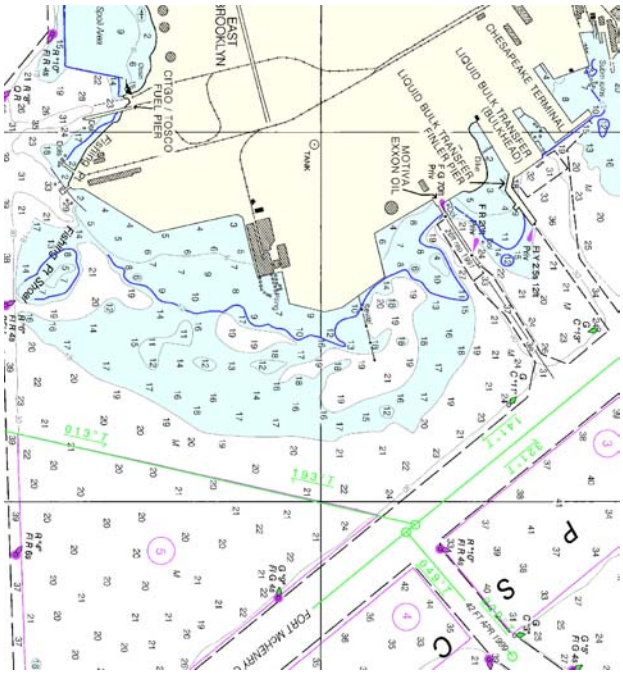

Figure 3c - Chart With Custom Overlay

Finally, Print on Demand, either in the "printer replacement" mode or with the advanced capabilities opens the door for point-of-sale printing. This was tried by NOAA in 1997 and found to be not appropriate at that time. The technology was not as easy to use as an office copier, and there are quality control issues that need to be watched closely. Further, the dynamic assembly of asynchronously changing

files into an up-to-date, customized chart was beyond the expertise of most chart sales agents. Finally, agents stated that they would print charts “one or two evenings a week”. This did not support the delivery of up-to-date charts as effectively as electronic ordering, immediate production, and overnight shipping which NOAA and OceanGrafix decided to start with. The issue of liability was not addressed.

Since then, the use of an inkjet plotter to print a static set of files has probably moved within the capability of more sophisticated chart agents and users. With the resolution of issues such as quality control; licensing, copyright, and revenue; liability; and file distribution and management (since suitable files can be very large), point-of-sale printing could probably be implemented.

Conclusions – Print on demand is ready for use by hydrographic offices. It can be used as a replacement printing process to reduce inventory and warehouse costs, and to avoid out-of-stock conditions. Print on Demand also offers the opportunity to make an improved nautical chart. It can make charts that are always up-to-date, charts that have been customized for market segments or individuals, and charts with special physical characteristics. Electronic commerce proved to be a natural “front end” for Print on Demand, and an excellent way to specify a dynamic product. Together, they can be a transformational technology that lets hydrographic offices improve and expand their products. As more offices begin to update charts every week, it would be an easy step to share files so that a hydrographic office could print up-to-date charts on behalf of another hydrographic office at any location in the world.